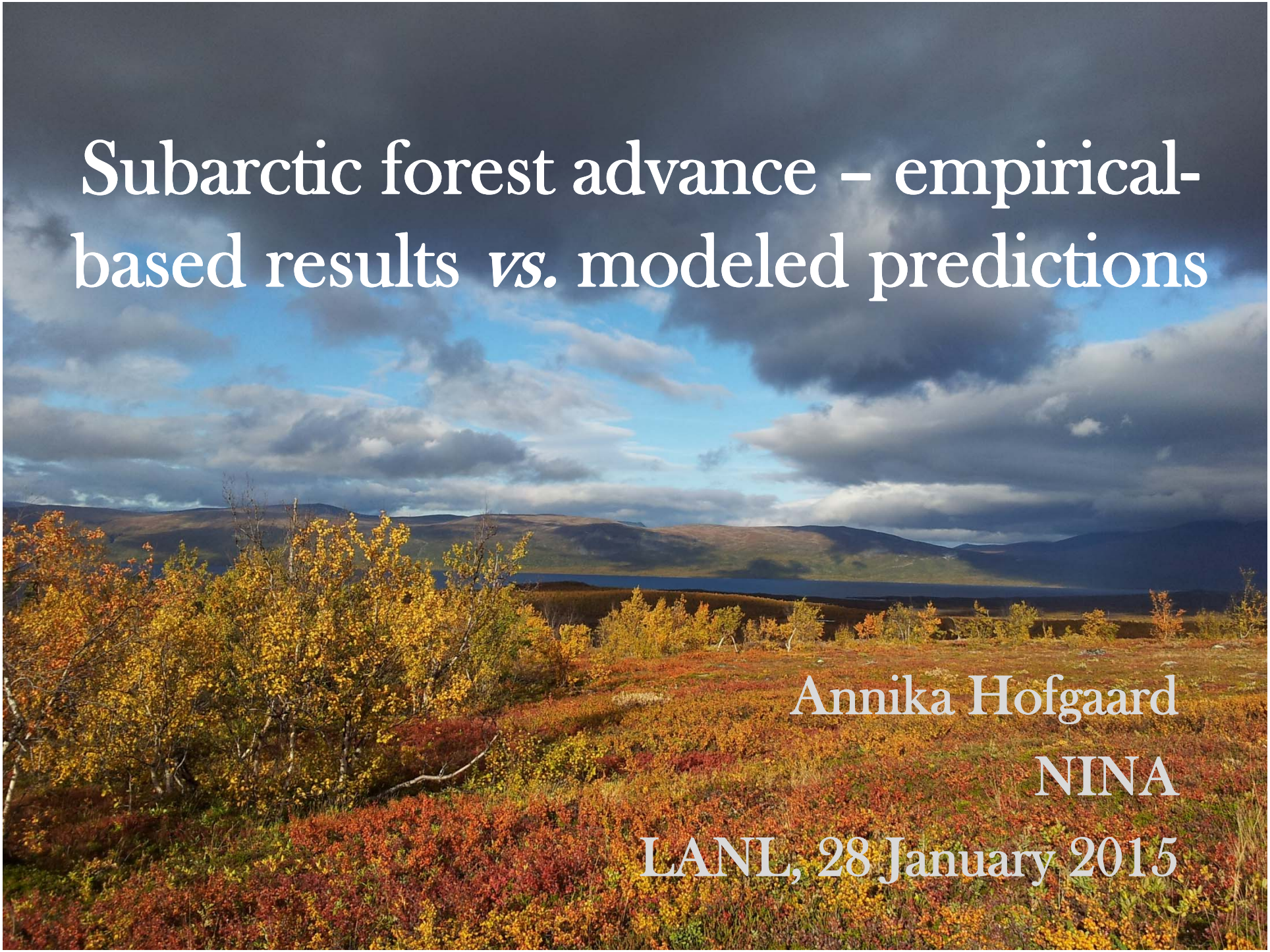


Subarctic forest advance – empirical-based results *vs.* modeled predictions

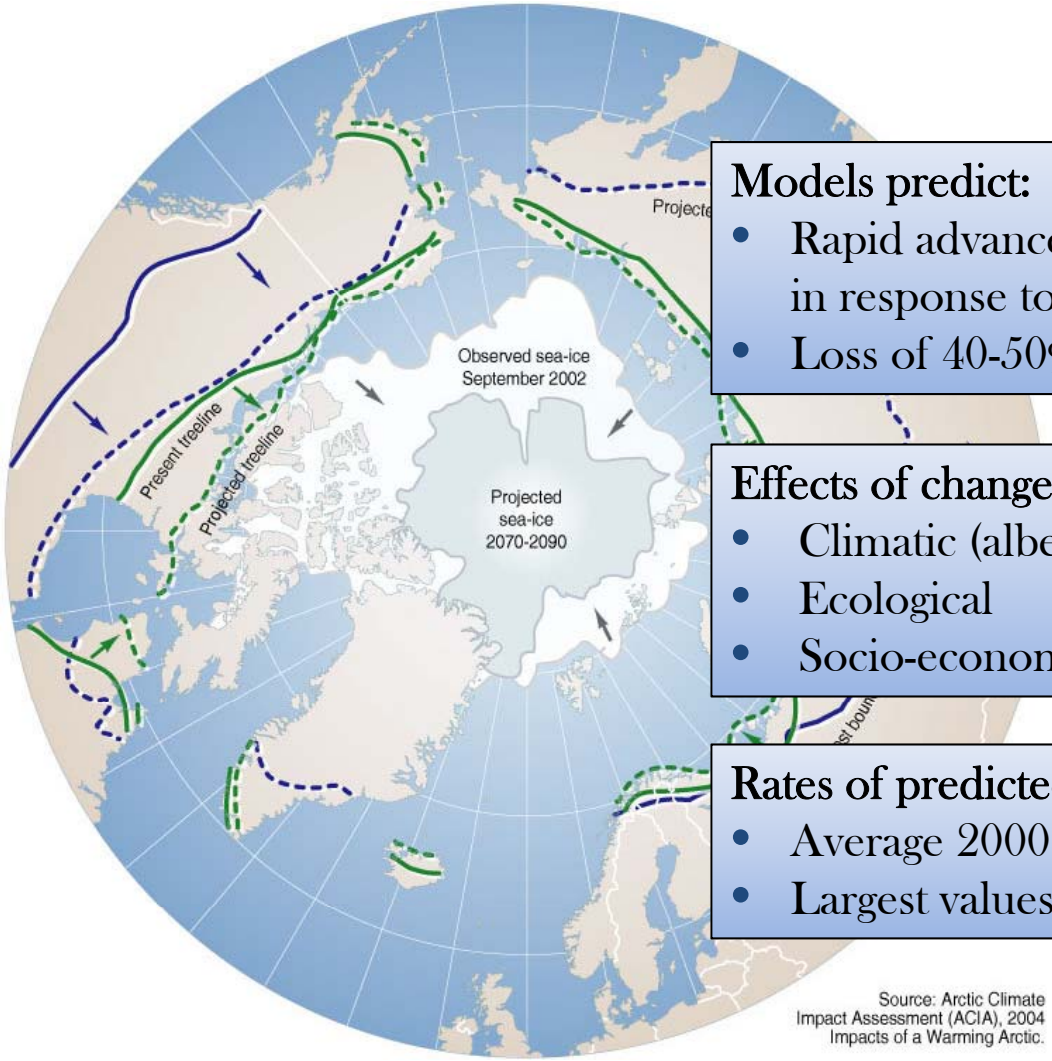
Annika Hofgaard
NINA

LANL, 28 January 2015

Today

- Background
- Common expectations
- Definitions
- Change and consequences
- Results from northern Europe
- Circumpolar pattern

Why focus on the subarctic forest?



Source: Arctic Climate Impact Assessment (ACIA), 2004 Impacts of a Warming Arctic.

Models predict:

- Rapid advance of trees and shrubs in response to global warming
- Loss of 40-50% of current tundra

Effects of changed forest distribution:

- Climatic (albedo, GHG)
- Ecological
- Socio-economical

Rates of predicted advance:

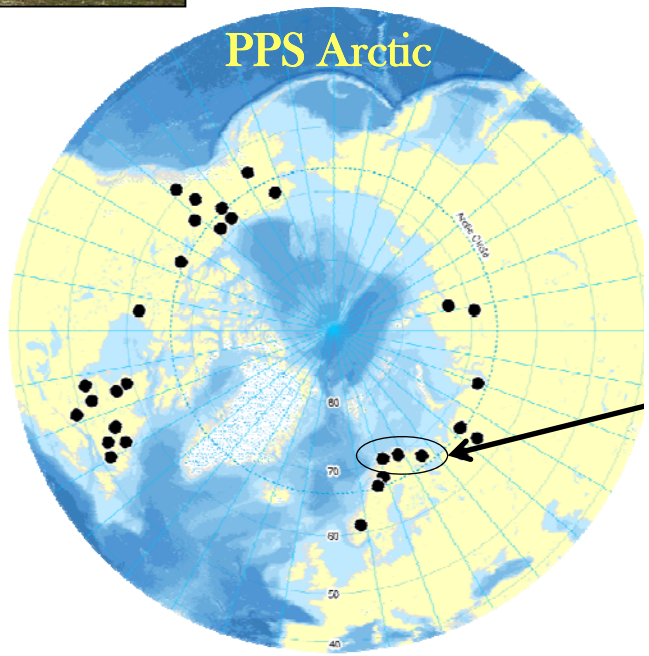
- Average 2000 m/y
- Largest values imply 6000 m/y

Common expectations

- Climate is considered one of the most important factors controlling forest-tundra ecotone dynamics
- As temperatures increase, the forest-tundra ecotone is expected to shift upwards and northwards
- The response is expected to be shown by swift tree and shrub advance

Basic questions

- Are trees invading the Arctic?
- Can the question be answered in a simplistic way? Where, why, how???
- Can site-based responses be translated into region-wide general pattern?
- Invasion to what rate?
- What response and rate regulating factors are dominating and at what scales?
- Implications of forest advance?



Studies include:

- seed production
- seed quality
- regeneration
- growth responses
- age structure
- spatial pattern
- soil
- animal interference
- land use
- socio-economy
- mapping
- experiments
- remote sensing
- climate data
- historical archives

- >60 Graduate students
- 8 Postdocs
- 32 PIs
- Many students, assistants, locals
- 31 Institutes
- 10 Countries
- 35 presentations at the IPY 2010 Conference
- 27 presentations at the IPY 2012 Conference

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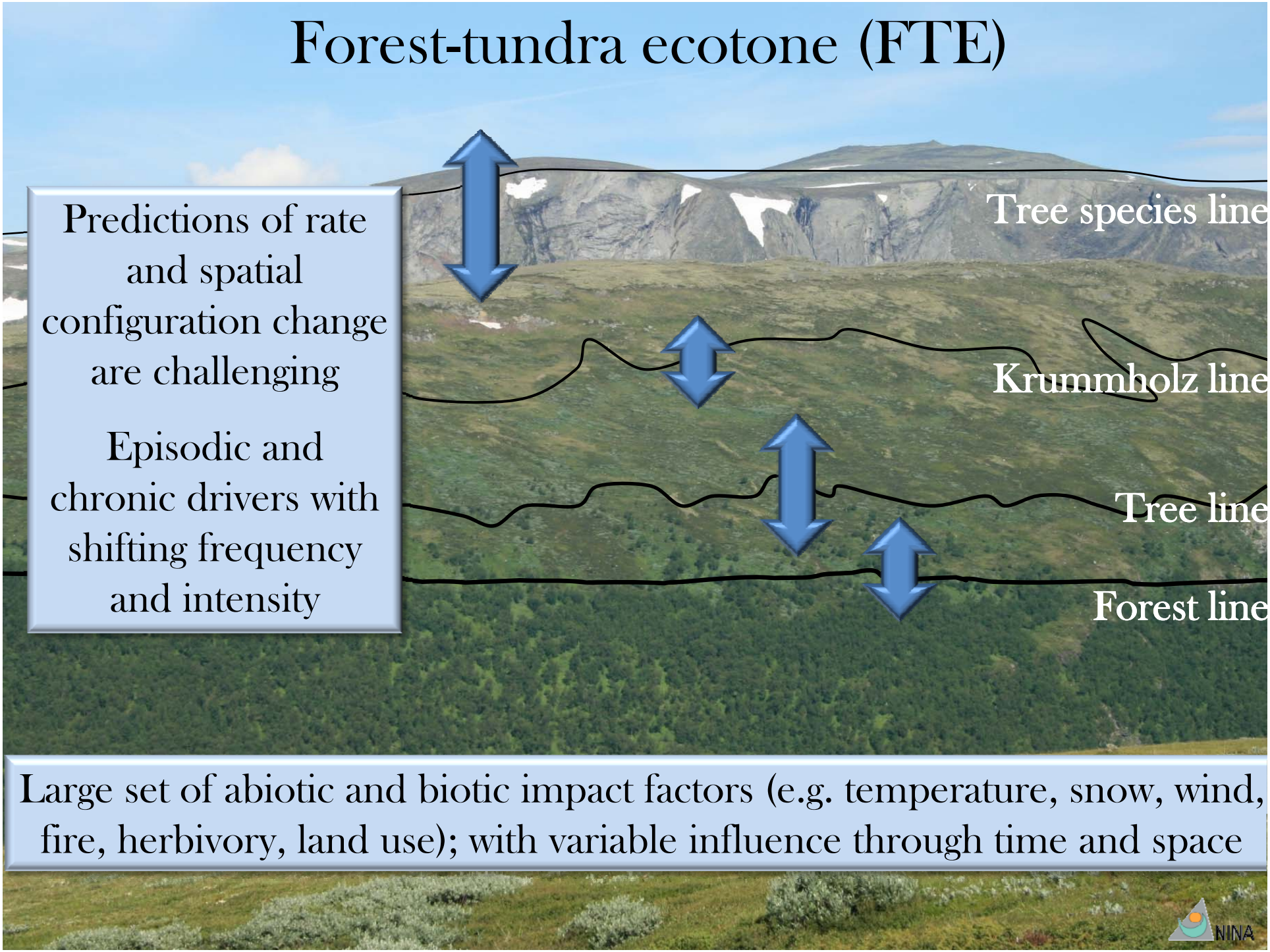
Forest-tundra ecotone (FTE)



Predictions of rate and spatial configuration change are challenging

Episodic and chronic drivers with shifting frequency and intensity

Large set of abiotic and biotic impact factors (e.g. temperature, snow, wind, fire, herbivory, land use); with variable influence through time and space

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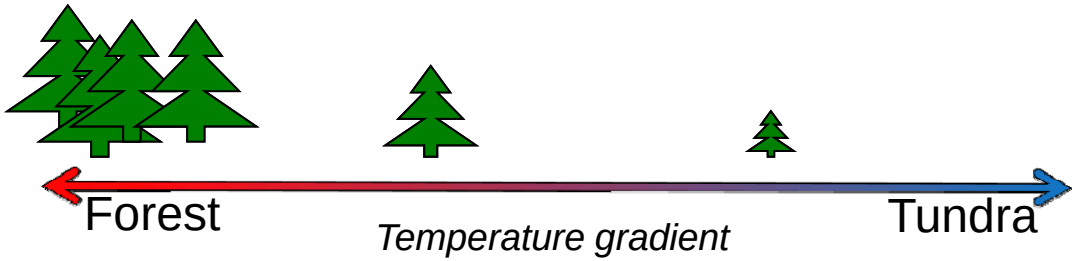
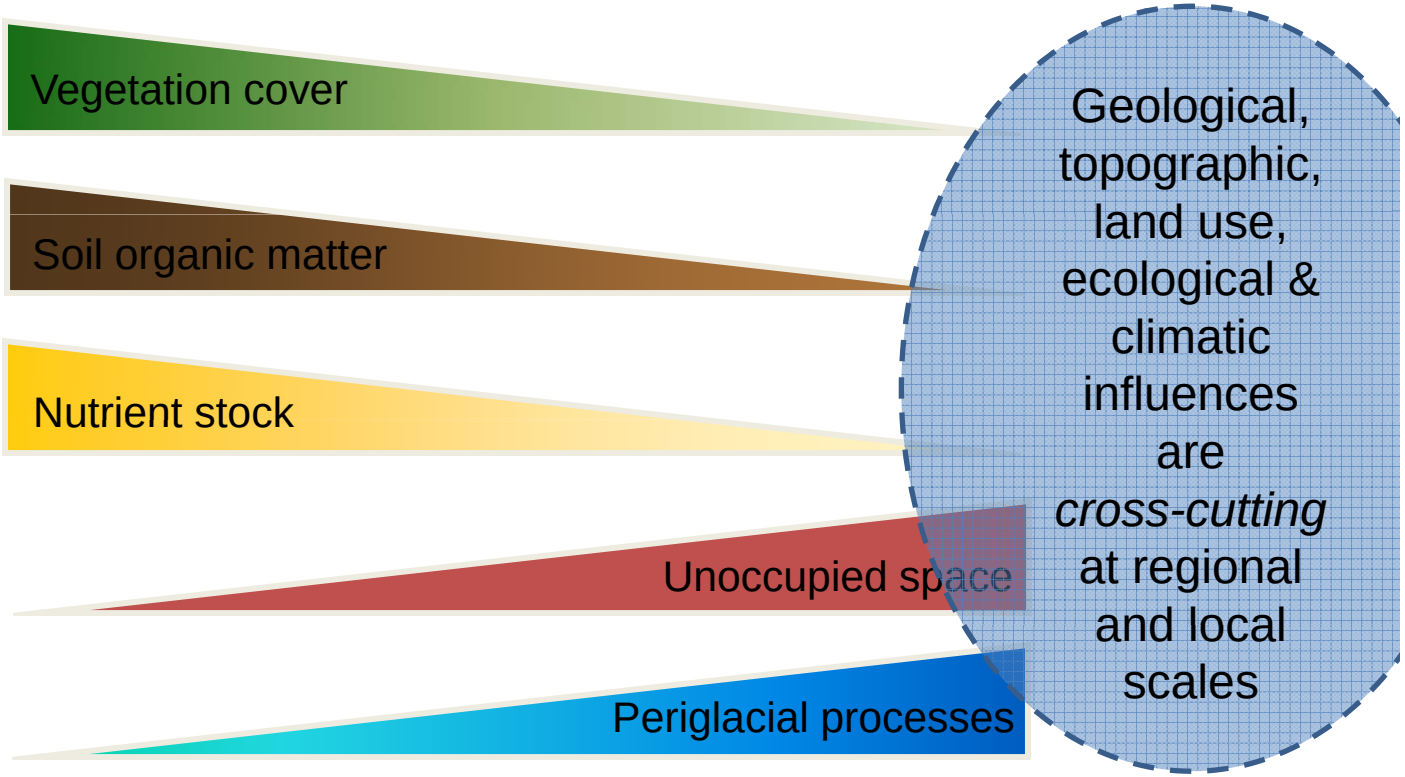
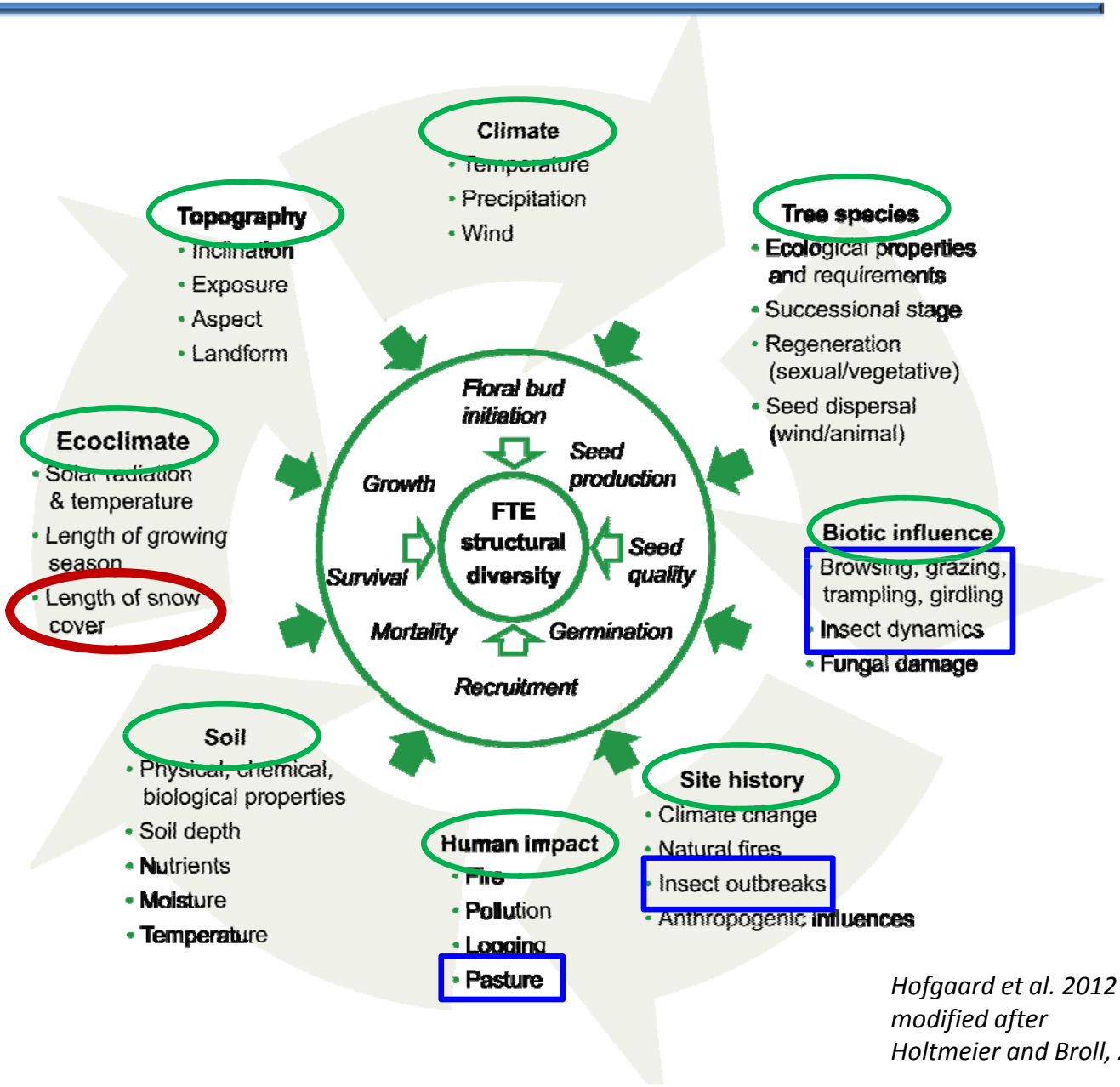
Characteristics of FTE



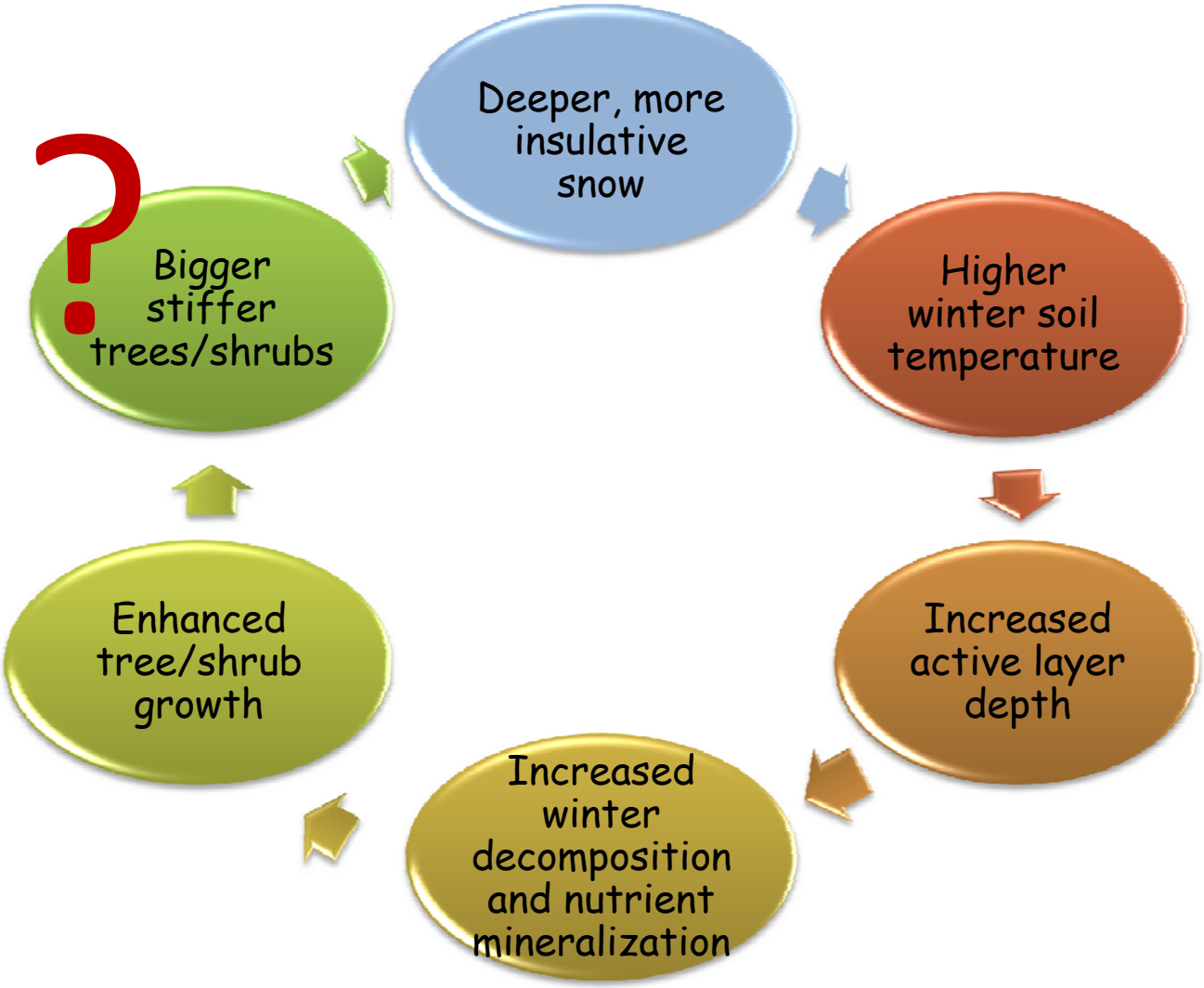


Drivers of FTE

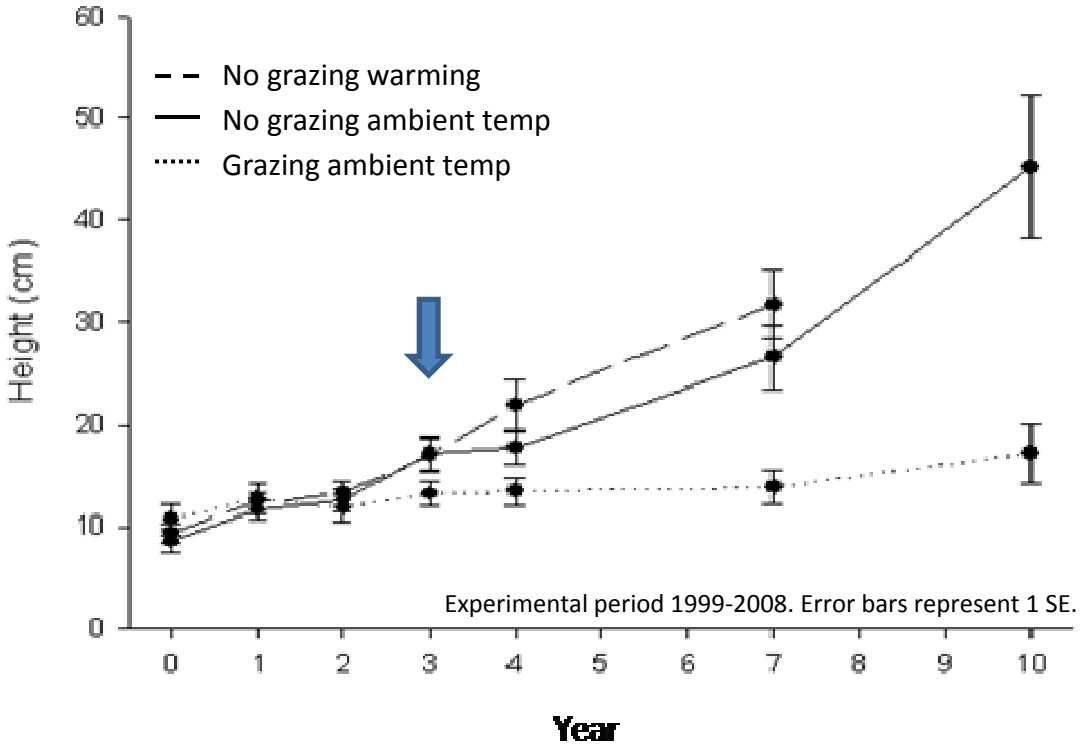


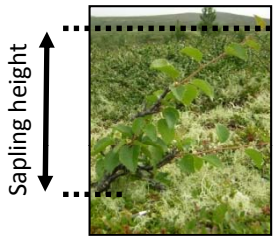
Hofgaard et al. 2012
modified after
Holtmeier and Broll, 2005

Impact of snow cover change



Tree/shrub height growth in the tundra environment

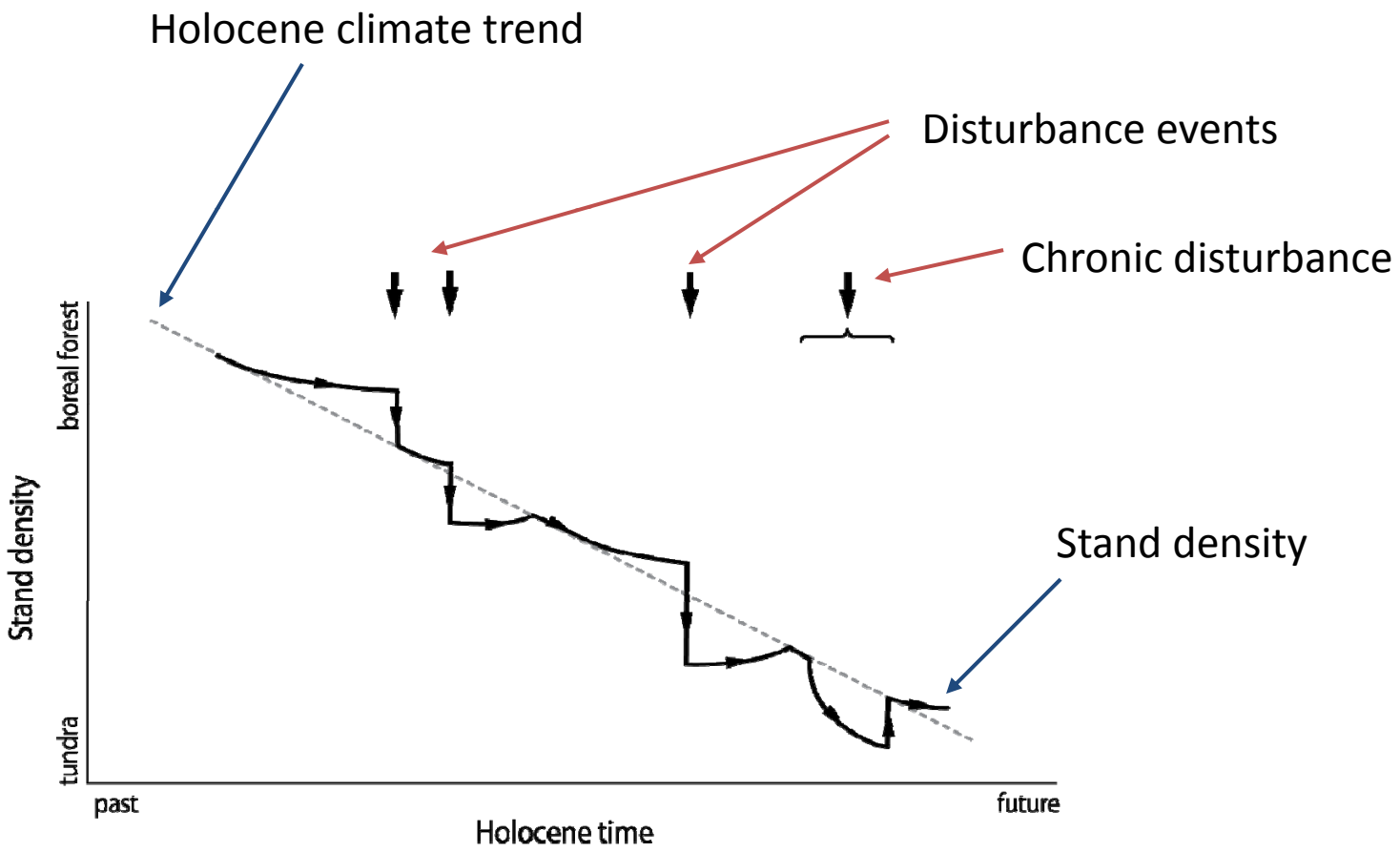




The experiment show grazing controlled response to environmental change, with climate (warming) as a secondary force. This herbivore-driven concealing of expected climate-driven tree/shrub expansion emphasizes the necessity to consider changes in grazing regimes and other disturbances along with climate change.

Hofgaard et al. 2010

Role of disturbance through time



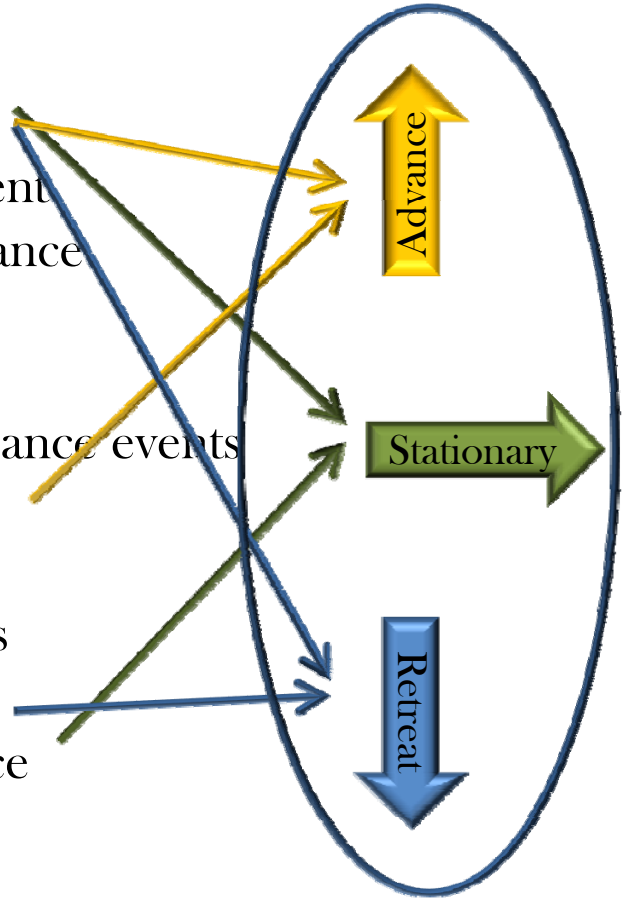
Hofgaard 1997

Current FTE movement

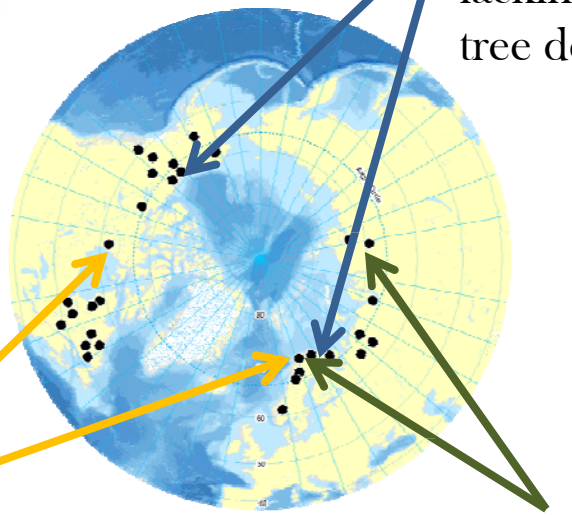
Enhanced climatic conditions
Recover from disturbance event
Release from chronic disturbance

Constant climate
Constant frequency of disturbance events
Constant chronic disturbance

Worsened climatic conditions
Frequent disturbance events
Intensified chronic disturbance



Site results - examples

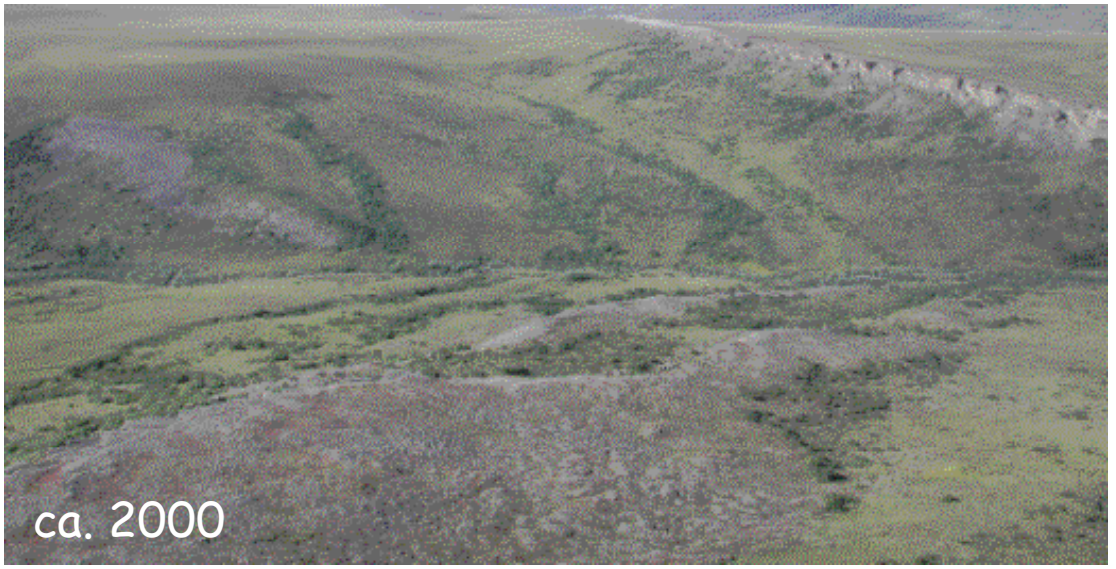


Retreating:
No recruitment; seeds are produced, but seedlings are lacking; trends sensitive to tree death

Stationary:
Seedlings are common, but low or no recruitment to the tree layer; trends sensitive to tree death

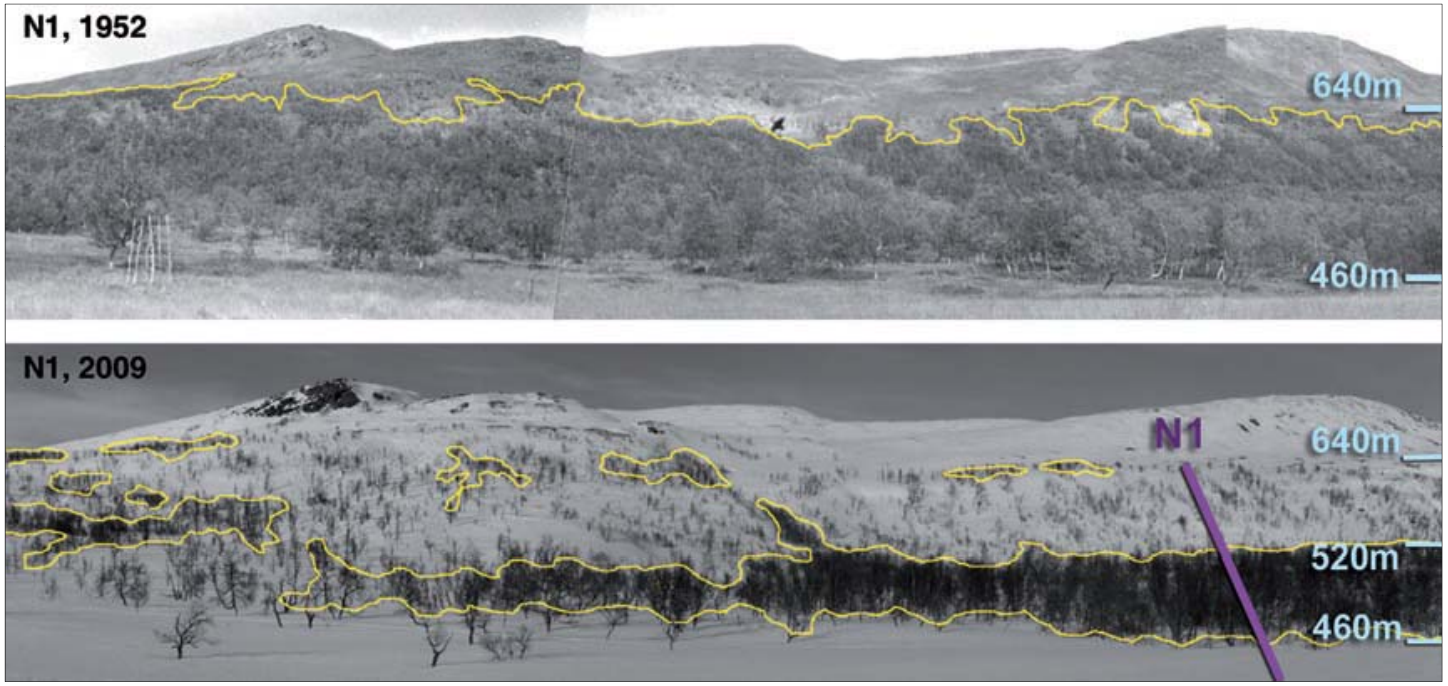
Advancing:
Seedlings and young trees are common; trends not sensitive to tree death

Increased shrub cover Brooks Range, Alaska



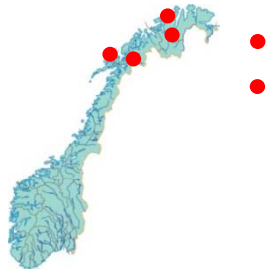
Sturm et al. 2001

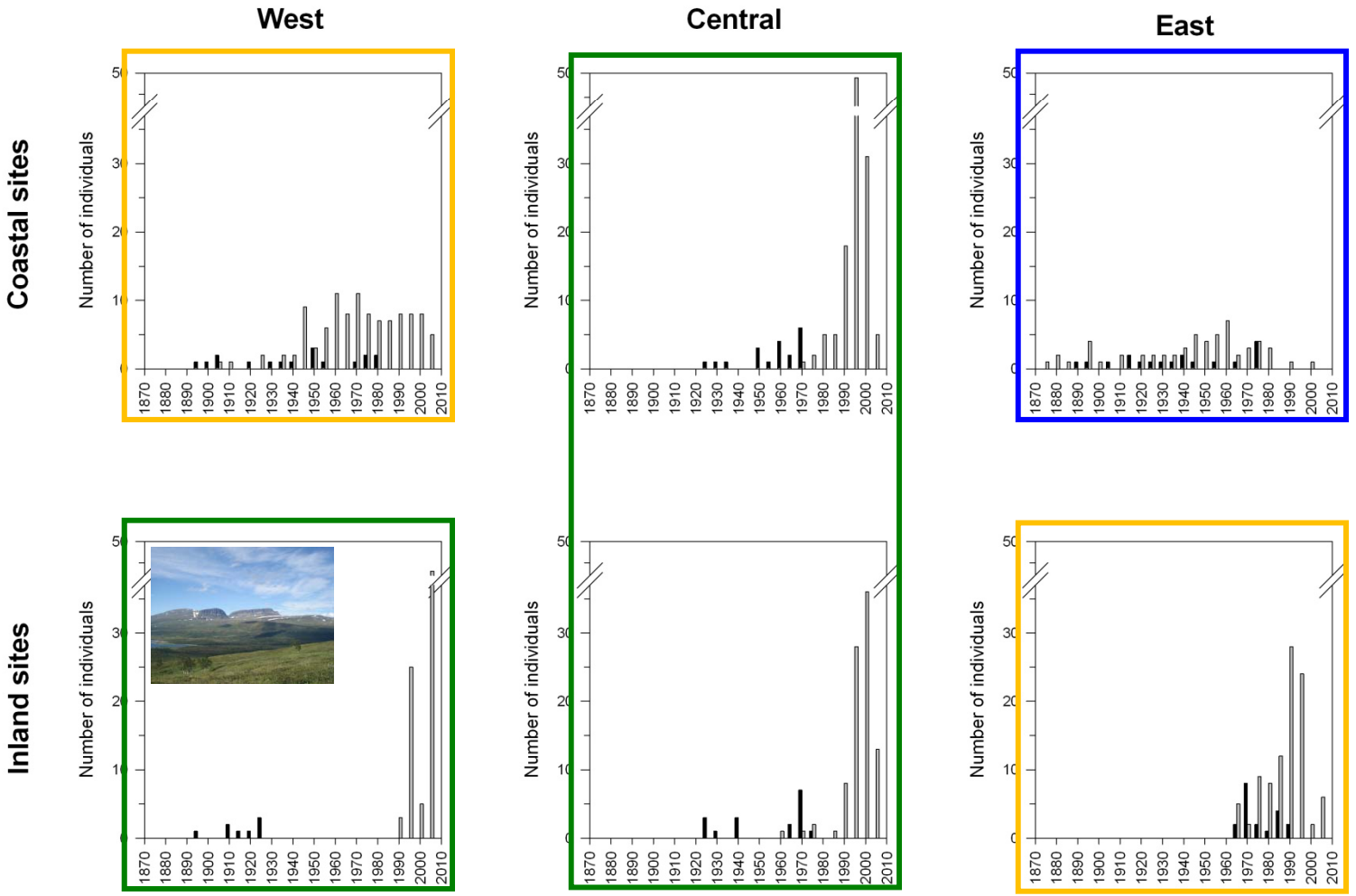
Decreased forest cover Abisko, N Sweden



Van Bogaert et al. 2011

Age structure evidence

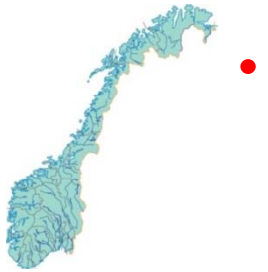




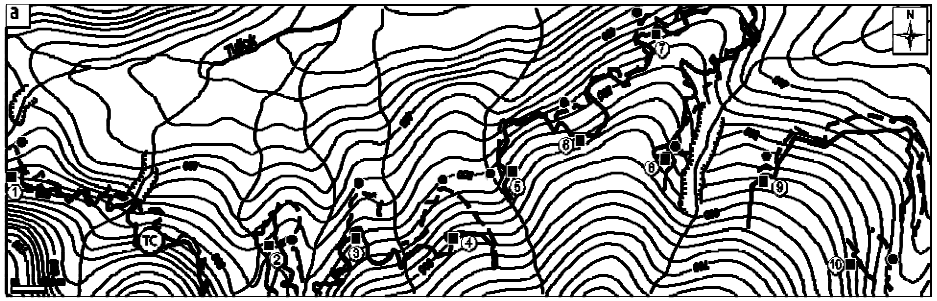
Treeline trees (black bars) and tree saplings beyond treeline (open bars)

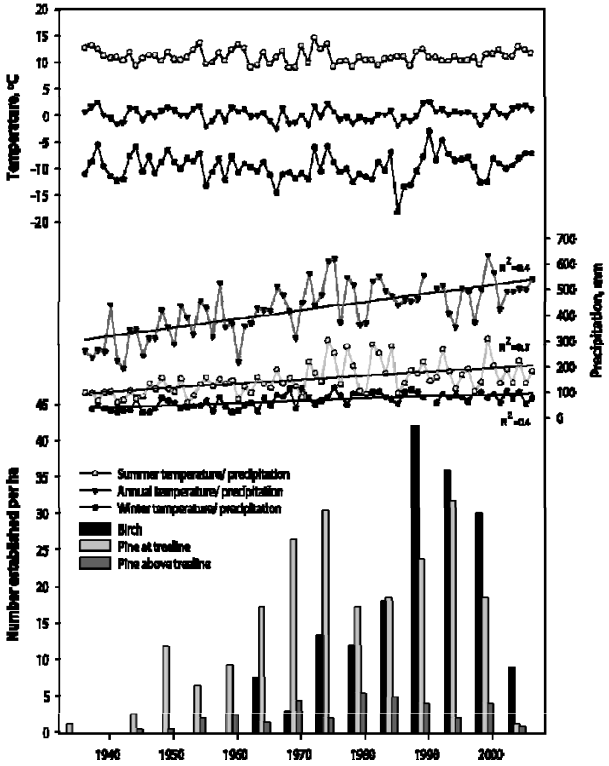
Aune, Hofgaard & Söderström, 2011

Khibiny Mountains, FTE change 1958 - 2008



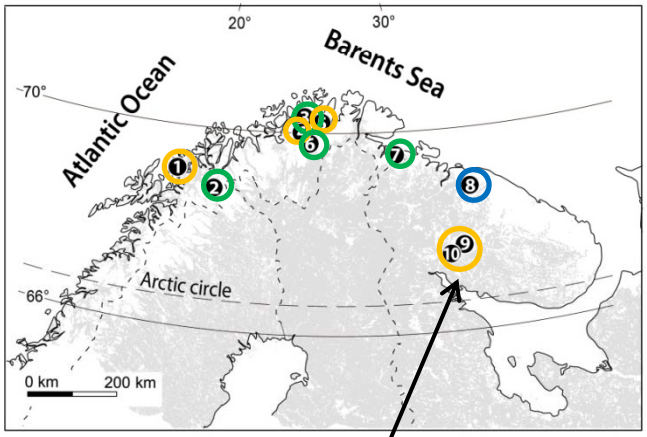
25-30 m altitudinal advance in 50 years

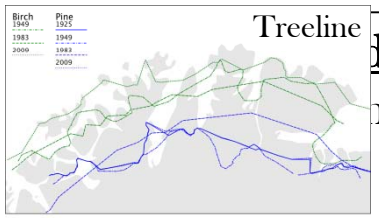


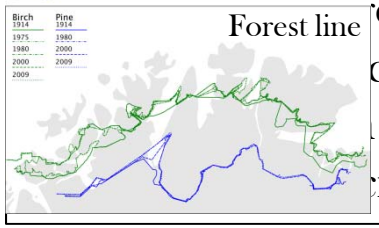


Mathisen et al. 2014

Sites *vs.* region - example







dividual sites

- Regional temperature increase: 2°C since early 20th century

ipitation

Site-based analyses:

Age structure
Spatial configuration
Recruitment pattern
Remote sensing

Advance, Stationary, Retreat

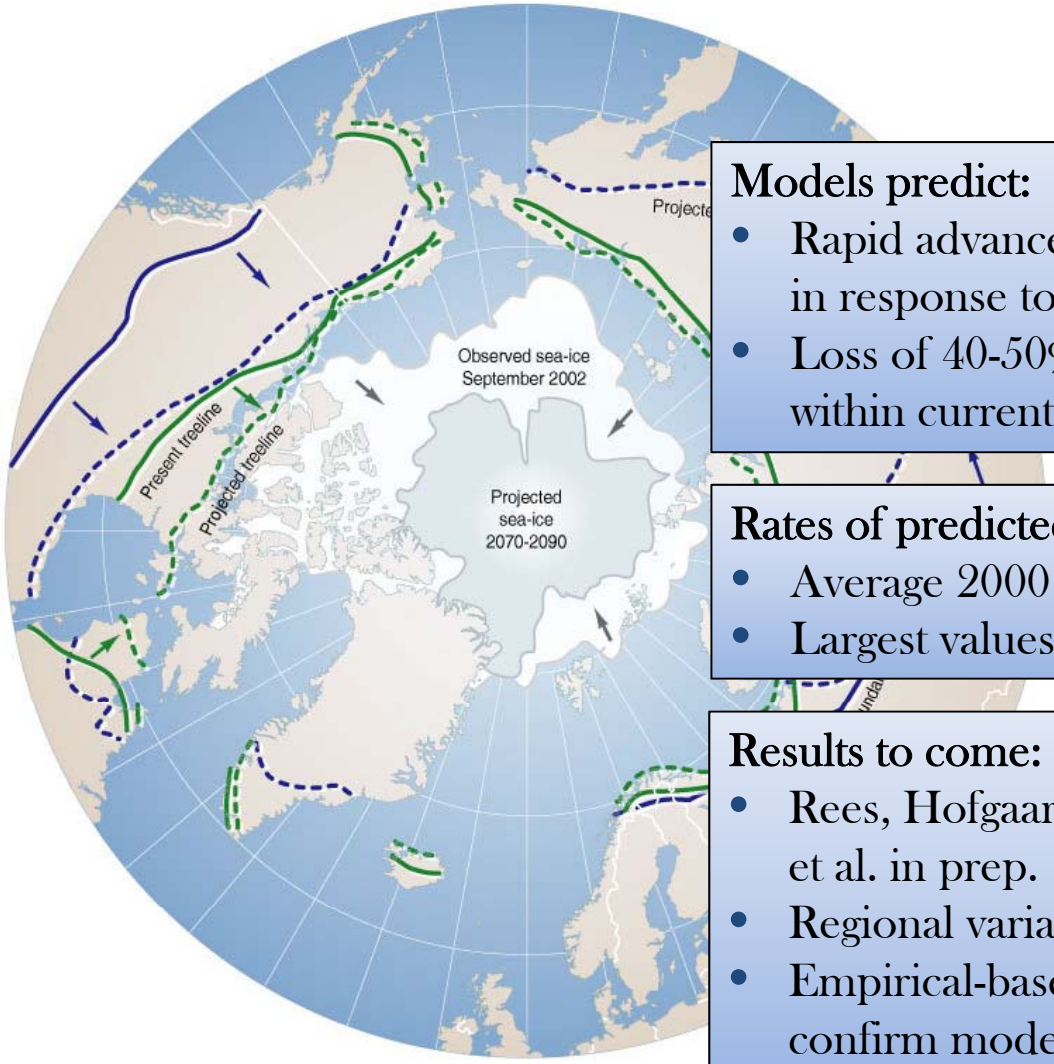
Advance rate of ca. 0.6 m/yr calculated for 1958-2008

Regional latitudinal advance:

- Average rate is of the order of 100 m/year
- Loss of tundra could be estimated as being ca. 2% at the end of current century

Hofgaard et al. 2013

Circumpolar pattern?



Models predict:

- Rapid advance of trees and shrubs in response to global warming
- Loss of 40-50% of current tundra within current century

Rates of predicted advance:

- Average 2000 m/y
- Largest values imply 6000 m/y

Results to come:

- Rees, Hofgaard, Cairns, Timoney et al. in prep.
- Regional variation
- Empirical-based results do not confirm model predictions

General conclusions

- Yes, trees and shrubs are moving north, but .....
- Where – local to regional perspective
- Why – causal background
- Mismatch between predictions and observations
- Mismatch between results based on experiments vs. natural (both rate and species-specific responses)
- Rate of advance – not km/year but meters/decade?
- Modelled tundra loss of 40-50% - a serious overestimate
- Multi-site analyses are needed to refine regional and circumpolar forest advance scenarios
- Further synthesis activities will prove helpful

Closing comments

- Herbivores can dominate the dynamics of the zone at region- and species-specific levels by modifying e.g. recruitment, survival and growth of trees and shrubs
- Disturbance-driven modification of expected climate-driven tree and shrub expansion emphasises the need to consider changes in grazing regimes and other perturbations (fire, insects etc.) along with climate change
- Between-site and between-region variation has to be considered
- If not - misleading interpretations regarding rates of climate-driven encroachment will prevail

Thanks!

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